Designing Hatcheries with Genes in Mind

Objectives
Students will: (1) describe the importance of genetic diversity; (2) understand that hatcheries must implement practices to maintain as much diversity as possible; (3) understand why salmon and steelhead runs become threatened, endangered, and extinct; (4) understand traits that allow fish to survive and reproduce.

Curricular Areas
Science, Language Arts

California Content Standards
GRADES 5-8
Science
6th: Ecology 5 e; Investigation 7 a, d, e
7th: Genetics 2 b, c, d; Evolution 3 a, e; Living
      Systems 5 d; Investigation 7 c, e
English Language Arts
6th   Speaking 1.0, 2.0
7th   Speaking 1.0, 2.0

Method
Students will analyze the simulated gene make-up of a group of salmon and discuss hatchery operations and decisions as they relate to genetic diversity.

Materials
- Time: allow (1) 50-minute class period
- Large clear jar or bowl
- Pony beads, eight different colors
- *Designing Hatcheries* information
- *Hatchery Operations Problems* worksheet
- *Hachery Cards* for clues

Background
Diversity is essential to the survival of a species. There are three kinds of biological diversity: diversity found in an individual, diversity within a species or a given population, and diversity within an ecosystem. The ability of an individual to survive changes in the environment comes from the extent of genetic diversity the individual has, thus giving it the ability to adapt to those variations. Diversity within a population means that there are enough organisms to continue producing a variety of genetic combinations within the group. The third type of diversity, biodiversity, deals with the ecosystem. A diverse ecosystem provides a variety of food sources for those living there, which allows for a higher survival rate.

In the world of "survival of the fittest," an organism must have the genetic resources that allow it to survive the immediate changes in its environment, and that allow the species to adapt to long-term changes around it. The only way to ensure this will happen is to make sure that the genetic choices in the population are large enough to have the greatest variety of attributes passed along to individuals to the next generation. The best way to ensure a large and healthy population with enough gene choices is to have sufficient habitat to support it.

Hatchery practices are crucial in maintaining the genetic diversity of a salmon run. There are nine salmon and steelhead hatcheries in California. Of these, three are state owned, four are federally owned and two are privately owned. The California Department of Fish and Game operates all but Coleman Hatchery, which is operated by the U.S. Fish and Wildlife Service. All but one of the hatcheries serves as mitigation effort for lost spawning habitat. Each hatchery has production outputs or quotas of salmonids that they must return to the river in either smolt or yearling size. Due to the variations in each river system, the hatcheries are operated according to their unique fisheries. This ensures the success of each salmon run.

Since salmon and steelhead hatcheries are located right on the river systems, it is not necessary for hatchery staff to capture brood stock. Instead, the fish come to the hatchery. Each pan of eggs taken contains eggs from at least two females, and milt from two males. This practice is to encourage the mixing of the genetic pool.

This activity presents students with several dilemmas

regarding operating a hatchery on a stream with wild fish present. While it has very general coverage of the issue of how to provide sport and commercial fisheries and protection of wild fish populations, at the same time, it should give students some insight into the factors that must be considered in hatchery operations.

Procedure

1. Have each student read the student sheet *Designing Hatcheries*.
2. Review the terms *genetic diversity* and *genetic traits*. Have students name a few genetic traits.
3. Divide the class into groups of two to four students. Give each group a copy of the *Hatchery Operation Problems.* Explain that each group of students will receive a small amount of colored beads. These beads represent the genes available in their salmon. Place all the beads in a glass jar, bowl, or plastic bag and mix the colors and give each group about a tablespoon full of beads. Explain that genes are distributed randomly in this activity just as in a real situation.
   a. Have students match their genes to the gene key and circle the colors or genes on the "Key to Genetic Traits" on the worksheet.
   b. Have students list the genetic characteristics of their salmon.
   c. Have students list genetic characteristics that are missing.
   d. How does the genetic make-up of their salmon affect its chances of survival?
   e. Have groups share their genetic make-up of each salmon. Is there genetic diversity within the salmon populations? Is there enough diversity to ensure a survival of some of the populations?
4. The key to the survival of salmon is to have the genetic resources, which cause adaptation to immediate changes in the environment, and allows the species to adapt to long-term change. This adaptation allows salmon to have a better chance of survival in their home stream than in any other.

5. Each group will now consider a hatchery operation problem and propose a solution for the problem.
6. Groups will be given a set of *Hatchery Cards*. These cards are to be divided equally between members of the group.
7. The group will use the clue cards to help formulate their answer to the problem. Once the decision is agreed upon by the group, they prepare an oral presentation for the class. This presentation will state the hatchery operation problem, the decision of the group, and a justification for that decision.
8. After each group presentation, have students review the clue cards and discuss the possibility of other decisions. Generally, the decisions should resemble the following:
   a. Decision 1: It is likely that fish from another stream have a different "library" of genes. These genes enable them to live just fine in their home streams but not in your stream. To ensure the success of your hatchery, you need to use fish from the stream you are trying to improve, because those fish have the best chance of survival in that particular place.
   b. Decision 2: Using fish from only a part of the run greatly limits the size of your gene "library." For instance, if you took fish from only the first part of the run, the resulting fish from your hatchery would be more likely to spawn early. This means that the *entire* population would be effected by a spell of flooding that occurred during spawning time. It would be far better to get fish from the entire run, which would conserve all the genes carried in the population. This would lengthen the spawning time and make it likely that some of the fish would spawn after the flood.
   c. Decision 3: Biologists estimate that in most situations, you would need at least 100 pairs of spawning salmon to maintain adequate genetic diversity in your hatchery fish population. More is better, so if you can take 300 pairs from your stream and still leave plenty of wild spawners to spawn in the stream, you should do it.

d. <u>Decision 4</u>: Increasing the spawning and rearing habitat makes room for more fish, both hatchery and wild, and therefore reduces competition. However, if the riparian and upland areas of the stream are being used poorly, your habitat improvements may not be successful.

e. <u>Decision 5</u>: Most habitats are "seeded," or full, and there is little room for more fish. The number of hatchery fish released has to be carefully watched to reduce disruption to wild fish. However, you could create more rearing areas in the stream to make room, making it possible to release your hatchery fish in sites not used by wild fish.

f. <u>Decision 6</u>: If your objective is to have more adults returning for anglers to catch, acclimate them to return to areas not used by wild fish. This reduces the chance that the hatchery fish will spawn with wild fish, and protect the wild fish gene pool. But, if you want the returning fish to spawn and be part of the (wild) stream-spawned-and-reared population, you want the adults to return to the natural spawning areas. This is a one-time operation that "jump starts" the population so that it will be self-sustaining in future generations.

g. <u>Decision 7</u>: You could close the trout fishery while the juvenile salmon are migrating to the ocean; this would prevent trout anglers from catching them by mistake. To protect returning adults, you could allow catch-and-release only for wild fish, marking (fin-clipping) the

Activity adapted from *The Fish Hatchery Next Door...* distributed by the Oregon Department of Fish and Wildlife.

Young Salmon Fry

Designing Hatcheries

Today there are about 20,000 different kinds, or species, of fish. These fish (and all living things) look and act the way they do because of traits they inherited from their parents. These traits developed over millions of years and many generations. Traits, such as the ability to grow a strong tail fin to propel the fish, a slime layer that helps the fish glide through the water, or a coloring that makes the fish difficult to find (camouflage), are easy to observe. But, some traits are not so obvious. The urge to migrate up a river to spawn, the ability to defend a feeding territory with great vigor, the drive to emerge from an egg in the gravel to the stream above, and resistance to disease are also inherited traits that help fish survive. These traits are passed along from generation to generation via structures called 'genes," which are contained in the sperm and eggs of the parents.

If all fish in a stream had the same genes, they would all react to a change in the environment in the same way. For instance, if a stream suffered a very low water year, and none of the fish had the combination of genes (the traits) to withstand a low-oxygen, warm-water environment, all of them would die. Luckily, fish in a stream do not have exactly the same genes. Over millions of years of spawning, wild fish populations built up a wide variety of genes, resulting in each fish with a slightly different makeup. Some of the fish in the stream probably would survive, because they inherited the ability to live in a warm-water, low-oxygen environment. These fish would be the basis of rebuilding a fish population in the stream. Some of these remaining fish would also have the inherited ability to survive in a cold-water, oxygen-rich environment, which would be important if the stream returned to its original condition.

This illustrates why every individual gene in a population is important, especially in a changing environment. The greater the differences in genetic makeup between members of the population, the greater the chances that some of the fish can survive environmental changes. It is like having a great library full of books (traits). If you threw away all the books that you didn't need at the time, you might be sorry later when you needed them again for some different information. In the case of fish, it is best to keep as many different genes as possible in the population. Biologists call this "genetic diversity." The goal is to have populations of fish (and all living things) with as much genetic diversity as possible. This is why wild fish are so valuable—because they have developed the most genetic diversity.

Suppose you had a situation in a stream where salmon spawning and rearing habitat was in short supply. Since wild salmon (the ones with the greatest diversity) depend on good habitat, wild salmon populations would be in short supply. So you decide to grow some salmon yourself and supplement the wild fish population with your own hatchery fish. Sounds like a good idea.... right? On the surface, raising a few fish to put into the stream seems fairly simple, and in

Hatchery Operation Problems

Key to Genetic Traits

Black	Tail Strength	Orange	Vigor (defending feeding territory)
White	Slime Production		
Yellow	Camouflage	Red	Drive to emerge from egg
Purple	Urge to return to spawn	Green	Resistance to disease

Each group must have one problem. The group should formulate a decision, use the clue cards for help, and prepare an oral presentation of the problem and the decision.

1. A run of salmon from a river system 100 miles to the south is particularly healthy and large. Does this sound like the place to collect males and females to provide eggs and sperm for your hatchery?

2. The run of salmon you want to use for your hatchery begins showing up on their natural spawning grounds in late October and continues until about the early part of January, with peak numbers during late November and early December. Circle the time period in which you would spawn fish for your hatchery:
   October   1-15-30   November   1-15-30
   December   1-15-30   January   1-15-30

3. Decide how many male and female fish you will need to provide adequate genetic diversity for the fish you will raise in your hatchery. You decide to spawn (circle one):
   10 pairs   25 pairs   50 pairs   100 pairs   300 pairs

4. You will be operating a hatchery on a stream or river. Would you need to also increase the spawning and rearing habitat in the stream?

5. You need to decide how many fish to release each year from your hatchery. Would you release as many as your hatchery can handle, or limit the number of fish you release each year?

6. Now you have to think about what will happen when your hatchery fish return to spawn. Would you acclimate your hatchery fish so that they would return to the areas used by wild fish for spawning, or acclimate them to return to areas not used by wild fish in your stream for spawning?

7. The stream your hatchery is located on has certain fishing regulations. What regulations would protect the wild and hatchery salmon as they migrate to the ocean and return to spawn?

Hatchery Cards

Fish are highly adapted to their home streams. Therefore, they have a better chance of survival in that stream than in any other.

The survival of a fish caught by an angler and later released depends on the careful treatment of the fish while playing it on the line and dislodging the hook. The least amount of handling is best.

Even fish from adjacent watersheds or river basins have different "libraries" of genes, which enable them to survive better in their own streams.

If you only collected fish for your hatchery from the early part of the run, the resulting offspring would likely all spawn early when they return as adults. Therefore, the entire population would probably be vulnerable to a spell of bad weather and flooding that may occure during spawning

When collecting eggs and sperm, you can get the greatest genetic diversity in your fish population by using the most fish possible.

One-hundred pairs of salmon are generally considered to be the minimum number needed to provide adequate genetic diversity to pass on to the next generation.

Using fish from various parts of a run would give you the largest genetic diversity in the offspring.

The number of fish collected from a stream to use as hatchery brood stock is dependent on the number of wild fish available in the stream. The key is to leave enough in the stream to insure there will be enough to sustain the genetic diversity of the next generation of wild fish.

Hatchery fry released into a stream where wild fry are living will compete with the wild fish for both food and space.

Increasing the habitat for spawning and rearing in stream makes room for more fish, both hatchery and wild.

Hatchery Cards

Creating better habitat in streams helps the wild fish population grow.

Habitat improvement projects in streams can be ineffective if riparian and upland areas of the stream are being poorly treated.

Most stream habitats are seeded, or full, and there is little room for more fish.

Smolts, or juvenile salmon, are usually released in the spring to migrate to the ocean. They are very similar to trout in appearance at this time.

All natural ecosystems have a limit on how many living things they can support, including streams. This is called the stream's "carrying capacity."

Many streams are closed to trout angling until late spring in order to protect salmon and steelhead smolts from being caught by trout anglers.

Hatcheries whose objective is to increase the number of returning adult fish for anglers can acclimate their fish to return to spawning areas not used by wild fish. This allows the wild fish population to reproduce naturally.

"Catch and release fishing," where some fish must be returned unharmed to the stream, protects wild fish while allowing hatchery fish to be caught.

Hatcheries whose objective is to produce returning adults that spawn and become part of the stream-spawned-and-reared population acclimate their fish to return to the stream spawning areas. This is a one-time operation, because the hatchery just wants to "jump start" a population so it will be self-sustaining in the future

Hatchery fish can be marked by clipping the adipose or other fins at the hatchery before they are released. This enables both biologists and anglers to identify the fish.